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Report FOR 2004-2	

Assessment of 1989 - 1991 Plantations in Lowland Nova Scotia (9-14 Years after Plantation Establishment)

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NOVA SCOTIA
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Introduction

Performance monitoring of Nova Scotia's plantations is a key component to the Province's overall sustainable forest management strategy. The investment in plantation silviculture ensures that harvest levels can be sustained or enhanced for future generations. The province has a network of research permanent sample plots that are used to generate growth projections for plantations yet there is a need to collect data on the operational success of plantations at the forest level. This survey provides summary data on the operational performance of plantations 9-14 years following establishment.

The survey assessed a representative sample of plantations established between 1989 and 1991, which were the peak years for planting in Nova Scotia. During this period close to 70,000,000 trees were planted in the lowland area of the province. This survey followed-up a survey completed in 1993 (NSDNR, 2003) and revisited the same plantations. Maintaining the original sample provided the consistency needed to understand early development patterns of plantations. The 1993 assessment reported on the success in establishing plantations, whereas this assessment reported the performance of those same plantations approximately 10 years later.

The purpose of the survey is to present plantation stocking, density and growth trends. A major concern with Nova Scotia plantations is the presence and density of natural regeneration. Baskerville (1984) points out that investments are made into plantations because they produce more merchantable volume in a shorter period of time compared to unmanaged stands. He also states that competition can easily unhinge these two basic advantages. The original survey (NSDNR, 2003) highlighted high levels of ingrowth 1-3 years after plantation establishment with the most influential factors being site disturbance, site preparation, drainage class and year of plant. This current survey looked closer at the influence of this ingrowth on plantation performance.

Methods

Plantation Selection

The intent of the survey was to revisit the population of plantations assessed in the 1993 survey. The 1993 survey sampled plantations that were representative of area planted by plant year, provincial subdivision (Figure 1), species planted and tenure class for the 1989 to 1991 time frame. For a more detailed summary of the plantation selection procedures see the 1993 plantation survey (NSDNR, 2003).

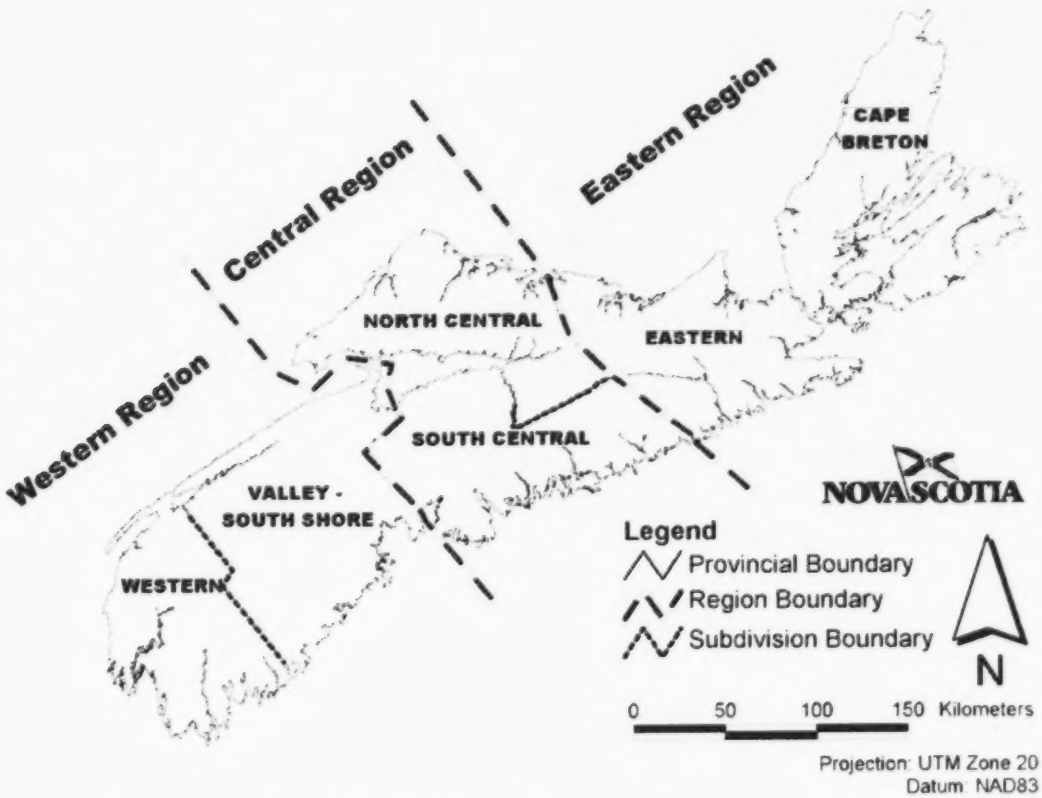


Figure 1. Subdivisions used for plantation selection.

Assessment Procedures

For each of the plantations revisited, the number of sample plots and their distribution were chosen to approximate the plot design used in the 1993 survey. The 1993 design was based on a 0.5% sampling intensity, restricted to a minimum of 10 plots and a maximum of 50 plots per plantation. Plots were established using a 2.1m radius and were further divided into four quadrants moving clockwise from the direction of the cruise line. The plot size was based on an average spacing of 1.8m by 1.8m. The design included one possible planted tree for each quadrant at the assumed spacing. The assessment procedure allowed for a flexible radius plot. If a plantable quadrant was empty the plot radius was extended 0.5m within which a planted tree would be tallied. Figure 2 shows an example of a plantation plot design.

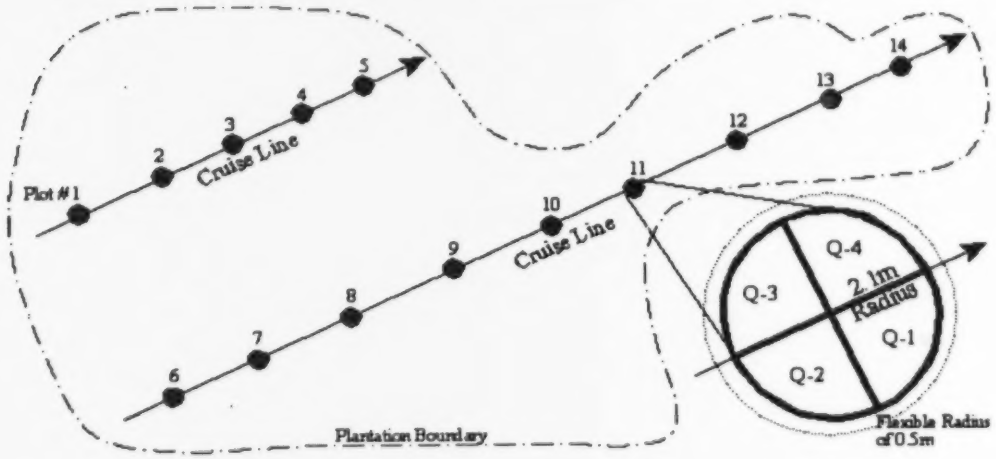


Figure 2. An example of a plot design used for plantation assessment.

Within each quadrant planted trees were assessed and tallied as either healthy, unhealthy or dead. Where more than one planted tree existed within a quadrant the extra planted stock was tallied by species within the excess stems category. If no planted stock was present, naturally regenerating softwoods were tallied as natural replacements. Natural replacements were not considered when they were less than half the height of the planted stock. Quadrants having no planted stock and no natural replacements were tallied as non-plantable where it was evident there was no suitable planting site. Finally if there was no suitable tree within a plantable quadrant then, it was tallied as missing.

Planted stock from the third quadrant of each plot, if available, was measured for total height and leader growth to the last complete growing season. If no tree existed in the third quadrant then the next quadrant having a planted tree was used. Height and leader growth data was not collected for natural replacements.

Excess stems within plots were recorded by species if they were at least half the height of planted stock. Excess stems could include planted stock where more than one planted tree existed per quadrant. Likewise any natural softwoods tallied as softwood replacements were not recorded as excess stems.

Average spacing measurements were taken along and across planted rows in each plot to the nearest tenth of a meter. Free to grow calls were made for each plot (yes or no). Plots were considered free to grow where crowns of planted stock were not being over-topped or impeded by competing vegetation.

For the plantation as a whole, competition and the necessity for treatment was assessed. Competing vegetation was tallied by species and included an assessment of the percent cover, average height and spatial distribution within the plantation. Four distribution classes were used which included; patchy, sporadic, uneven and uniform. For each plantation there was an assessment of whether a treatment was required in order to maintain the plantation. Plantations that required treatment had a prescription recorded. Additionally, where there was evidence of past treatments they were also recorded.

Results

Survey Description

The survey was started on May 26, 1999 with the last plantation assessed on June 13, 2002. Over this time period 285 plantations were assessed. This included the establishment of 5,564 plots over 1,589ha of plantation area. This works out to a sampling intensity of 0.5% by area which is consistent with the original objectives of the sampling design. Of the 348 plantations that were planned to be revisited 285 or 82% were actually reassessed which represented 67% of the total plantation area originally surveyed. The remaining 61 plantations (778 ha) were not assessed in this survey due to either time and/or access constraints. Two plantations (8.4ha of area) were revisited yet not assessed as one was replaced by a blueberry field and the other was lost to highway development. Figure 3 presents a summary of the plantations revisited by the various criteria targeted in the original sampling design.

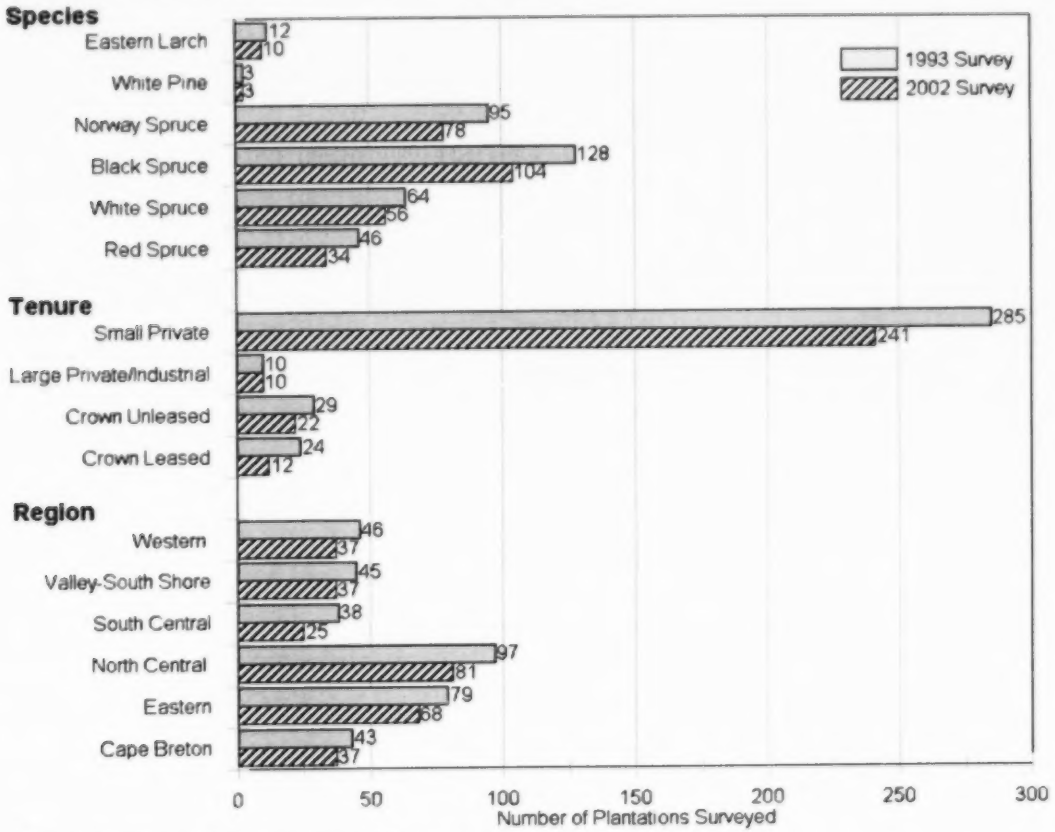


Figure 3. Plantations reassessed in comparison to the 1993 survey.

The 1,589ha of area sampled had an average plantation size of 5.6ha with a minimum of 0.2ha and a maximum of 34.0ha. Consistent with the original objectives, areas reassessed were well distributed across the provincial regions and subdivisions (Figure 4).

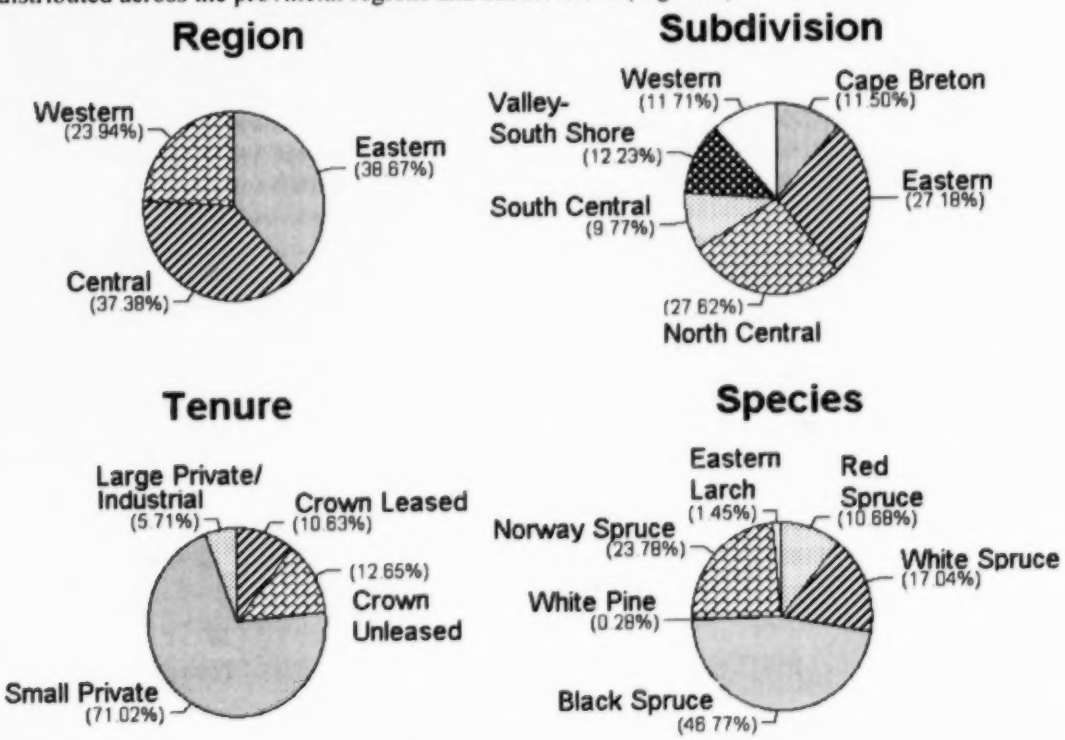


Figure 4. Plantation area assessed by region, subdivision, tenure and species.

The area distribution across the tenure classes (Figure 4) changed from the 1993 survey. Crown leased accounted for 27% in the 1993 survey as compared to 11% for the current survey. The crown leased category reflects plantations that, on average were the largest plantations assessed in the 1993 survey. In the reassessment, 50% of the leased crown plantations were revisited yet this represented only 25% of the associated area. Most of the larger plantations were removed due to time and/or access constraints. The area by species class (Figure 4) was relatively consistent with the 1993 survey, yet black spruce did increase from 39% to 46% while the white spruce decreased from 25% to 17%.

Stocking

Over the 1,589ha assessed, the area weighted average stocking of commercial softwood species (planted and natural) to plantable area was 81.6% (ranged from 15% to 100%). This was down from the 84.9% determined in the 1993 survey. Stocking of planted trees to plantable sites was 73.2% (ranged from 8% to 98%) compared to 84.1% in the 1993 survey. This suggests a decrease in survival that is being somewhat offset by natural replacements. A 1985 assessment (NSDLF, 1988) carried out on private land in Nova Scotia reported commercial softwood stocking at 77% and planted stocking at 72% for plantations originating between 1978-1984. The lower commercial stocking in the 1985 survey is likely due to differences in site disturbance history since the 1985 assessment included a higher percentage of old fields that tend to have less natural regeneration.

Total stocking levels that considered plantable and non-plantable area decreased slightly from the stocking levels reported above that considered plantable area only. For commercial softwood stocking (planted and natural trees), the stocking level decreased from 81.6% to 81.2%. For planted trees the average stocking decreased from 73.2% to 72.9% when non-plantable areas were included in the calculation.

An analysis of commercial softwood stocking classes for plantable area showed that 62% of the area assessed had stocking greater than 80% and 94% of the area was stocked to greater than 60% (Table 1). These numbers were down from the 1993 survey where 70% of the area was greater than 80% stocked and 96% of the area sampled was greater than 60% stocked.

Table 1. Commercial softwood stocking class area distribution.

Stocking Class[1]	Number of Plantations	Area (ha)	Percentage of Total Area (%)	Cumulative % of Total Area
100 - 81	169	986.0	62.0	62.0
80 - 61	89	503.3	31.7	93.7
60 - 41	22	82	5.2	98.9
40 - 21	4	15.3	1	99.8
20 - 0	1	2.6	0.2	100.0
Total	**285**	**1589.2**	**100.0**	**n/a**

1. Stocking class represents commercial softwood (planted and natural) stocking of plantable area

Regional, tenure and species based differences in stocking are summarized in Figure 5. Among the regions the central region (south central & north central) showed the higher stocking levels followed by the eastern region (eastern & Cape Breton). The western region showed the lowest stocking levels. These results were different from the 1993 survey where the highest stocking levels were in the western followed by central then eastern.

There were relatively small differences in commercial softwood stocking among the tenure classes (Figure 5). Average commercial softwood stocking levels ranged from 80.9% to 84.5% and average planted stocking levels ranged from 72.7% to 75.7% across all tenures. The 1993 results (NSDNR, 2003) showed higher levels of variation in stocking among tenure class.

Commercial softwood stocking among the different species varied from a high of 85% for white pine to a low of 75% for eastern larch (Figure 5). Both extremes are associated with species that had considerably less area sampled. Less variation existed between the major planted species where commercial softwood stocking ranged from 79% to 84% and planted stocking ranged from 68% to 77%. White and black spruce showed relatively higher planted stocking levels than the Norway and red spruce suggesting better survival. The 1993 survey reported that 83% of all severely browsed plantations were Norway spruce and red spruce was severely affected by hylobious and over winter damage.

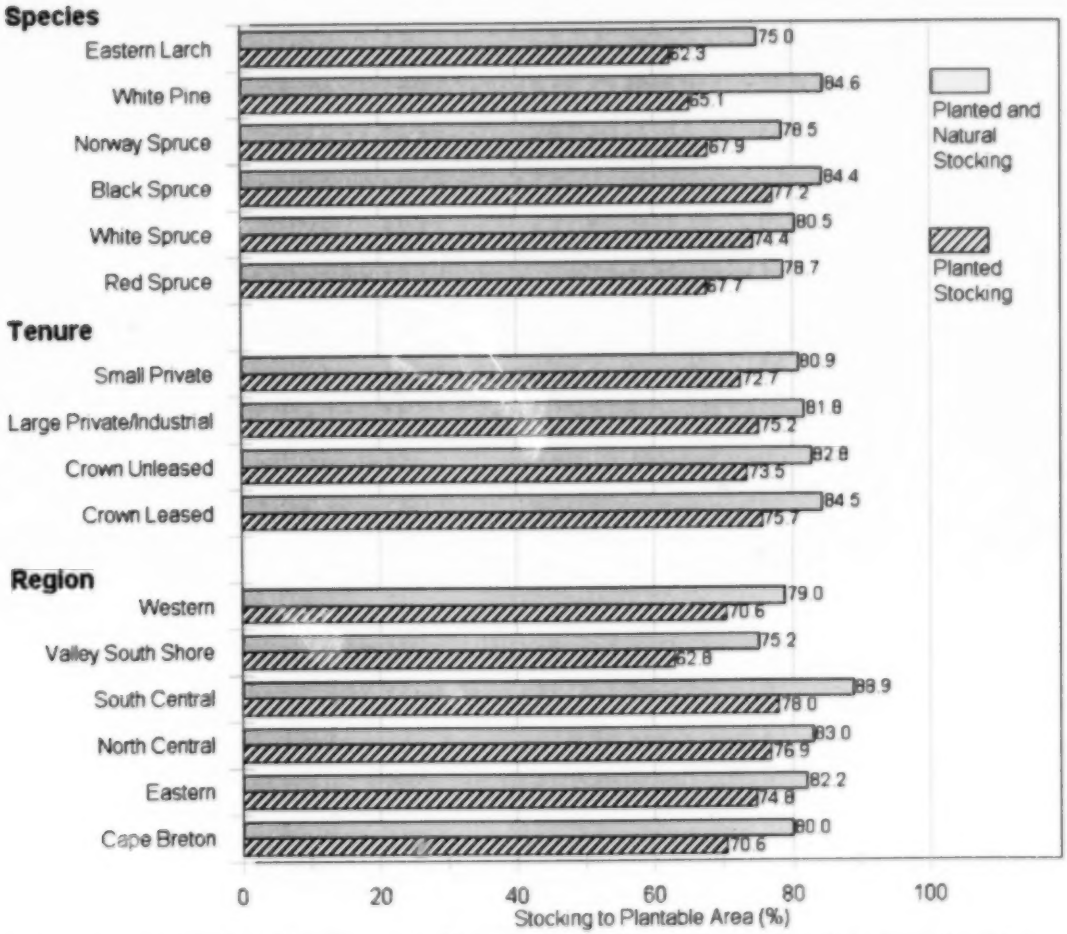


Figure 5. Area weighted average stocking to plantable area by region, tenure and species.

Survey results showed average stocking levels decreased with plantation age. Over the 9 to 14 year age range sampled, both the commercial softwood and planted stocking showed decreasing trends (Figure 6). This trend was also evident in comparison to the 1993 survey results, over the 10 years between the surveys stocking dropped about 4% on average. Both findings suggest that plantation stocking tends to decrease as plantations develop.

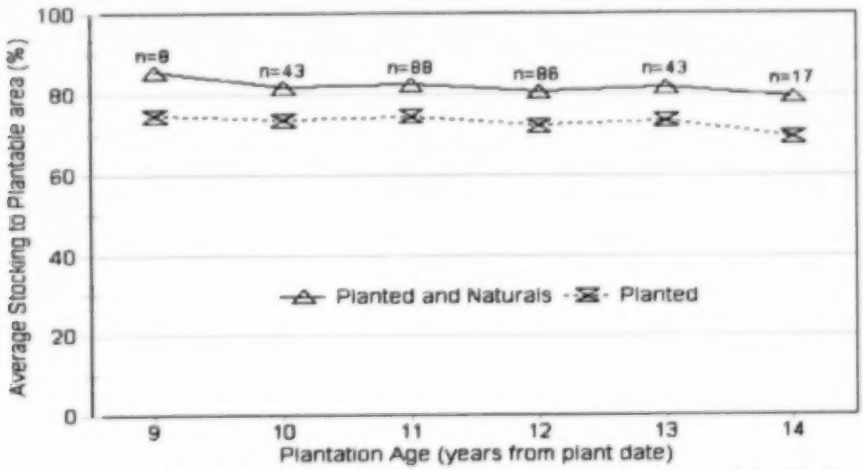


Figure 6. Area weighted average stocking to plantable area by plantation age.

Height

Analysis of the planted trees measured showed the area weighted average height of trees to be 2.36m with associated average leader growth at 36cm. These results were based on plantations that averaged 11.5 years of age and ranged in age from 9 to 14 years at the time of measurement. Both height and leader growth showed an increasing trend with plantation age (Figure 7) a result consistent with the 1993 survey.

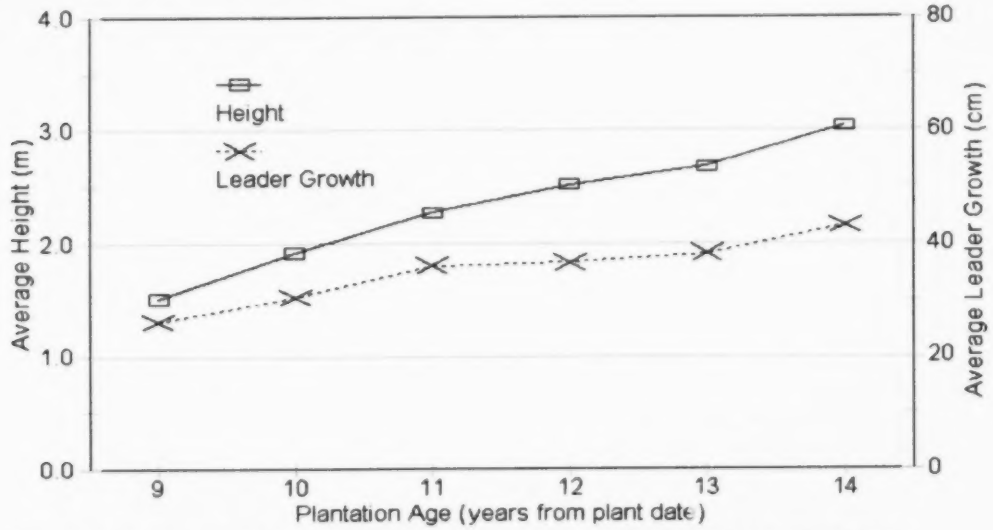


Figure 7. Area weighted average height and leader growth by plantation age.

The area weighted average height and leader growth across the different geographic regions showed that the eastern region (eastern & Cape Breton) was doing marginally better than both the central and western regions (Figure 8). The average height and leader growth by tenure did not show any trends (Figure 8).

Differences in average height and leader growth among planted species were evident in that eastern larch out performed the other species (Figure 8). Red spruce on the other hand showed height and leader growth considerably less than other species. This is consistent with other studies that identified the red spruce as a slower starter (NSDLF, 1989). The remaining species showed relatively smaller variations in the average height and leader growth. Black and white spruce showed the largest heights on average with white having a slight edge. Average leader growth among the black, white and Norway spruce was similar (Figure 8).

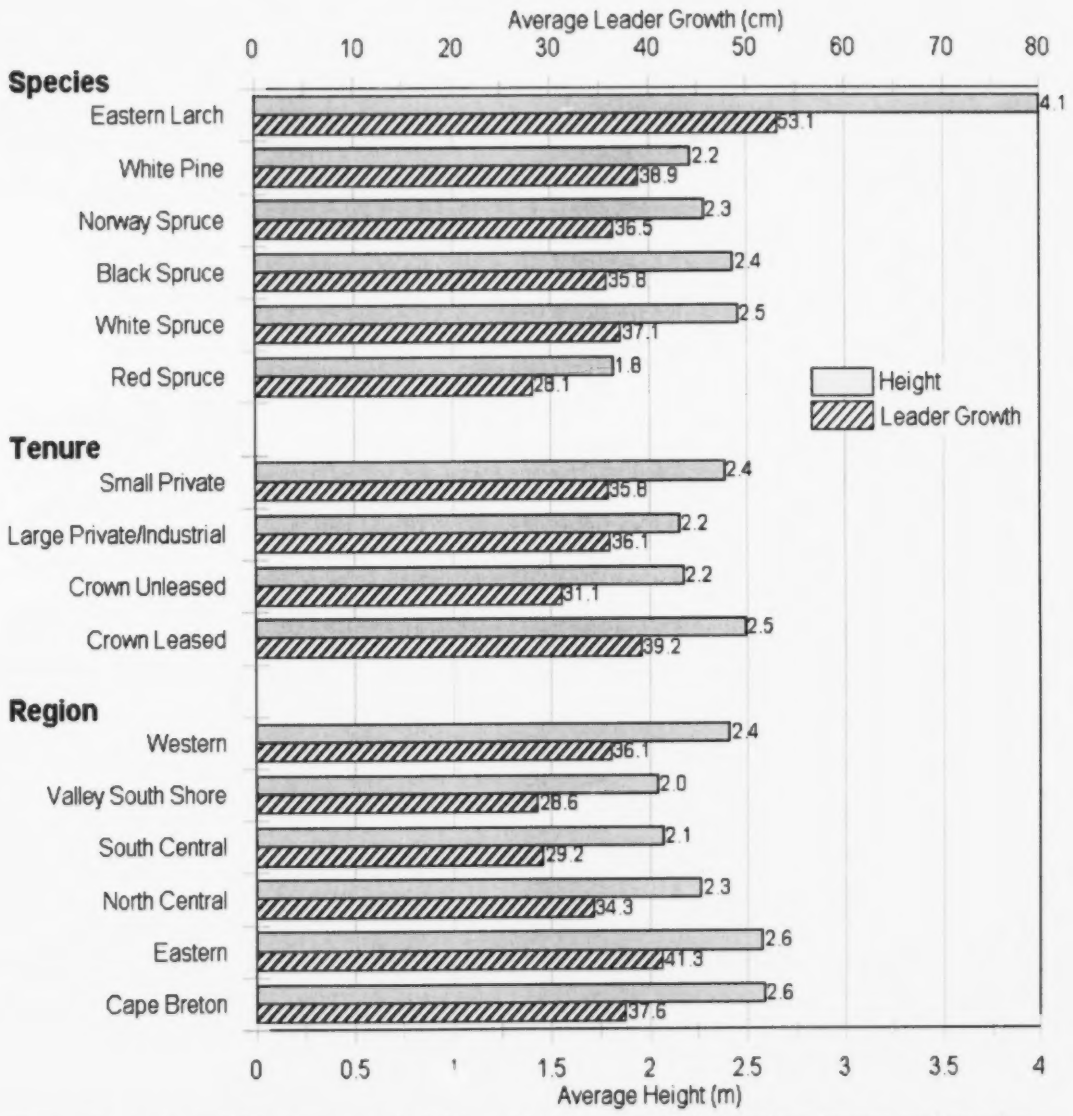
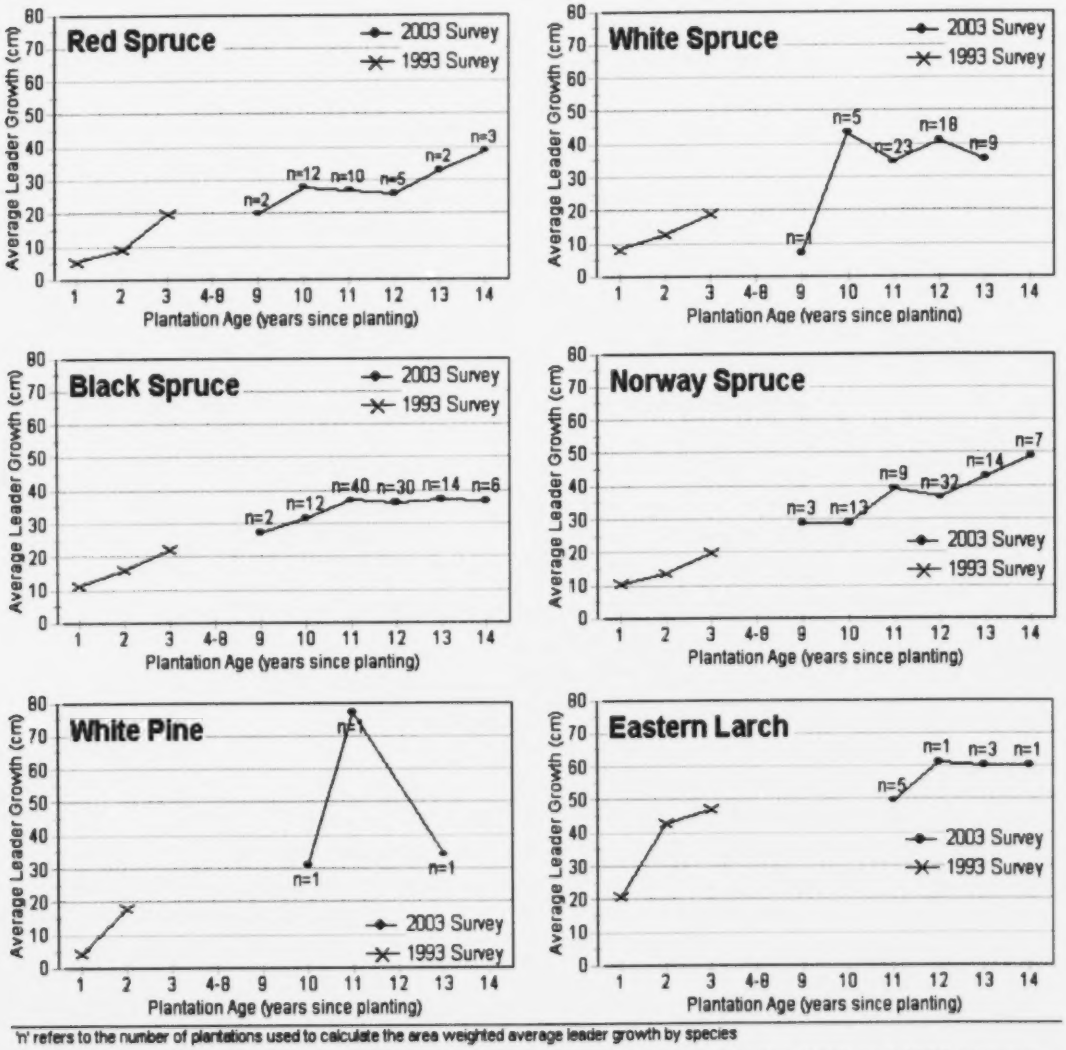


Figure 8. Area weighted average height and leader growth by region, tenure and species.

Similar to what was done in the 1993 survey, leader growth was plotted by species and age (Figure 9). The eastern larch showed average leader growth which was higher than the spruces and levelled off in the 60cm range by age 12. The 1993 survey also found eastern larch to have more leader growth on average (Figure 9). No conclusive trends could be inferred for white pine because of the high variability in average leader growth and small sample size. Of the spruces the Norway showed the fastest growing leaders and a growth rate that is still increasing. The white and black showed a similar development pattern to age 11 after which the growth rate

levelled off in the 40cm range. Red spruce showed the slowest growing leaders (Figure 9). Although it was slower starting out, the leader growth rate has not levelled off unlike the white and black spruce. Similar to other studies the results are suggesting the leader growth of red spruce will soon catch up to the black and white spruce (NSDLF, 1989).

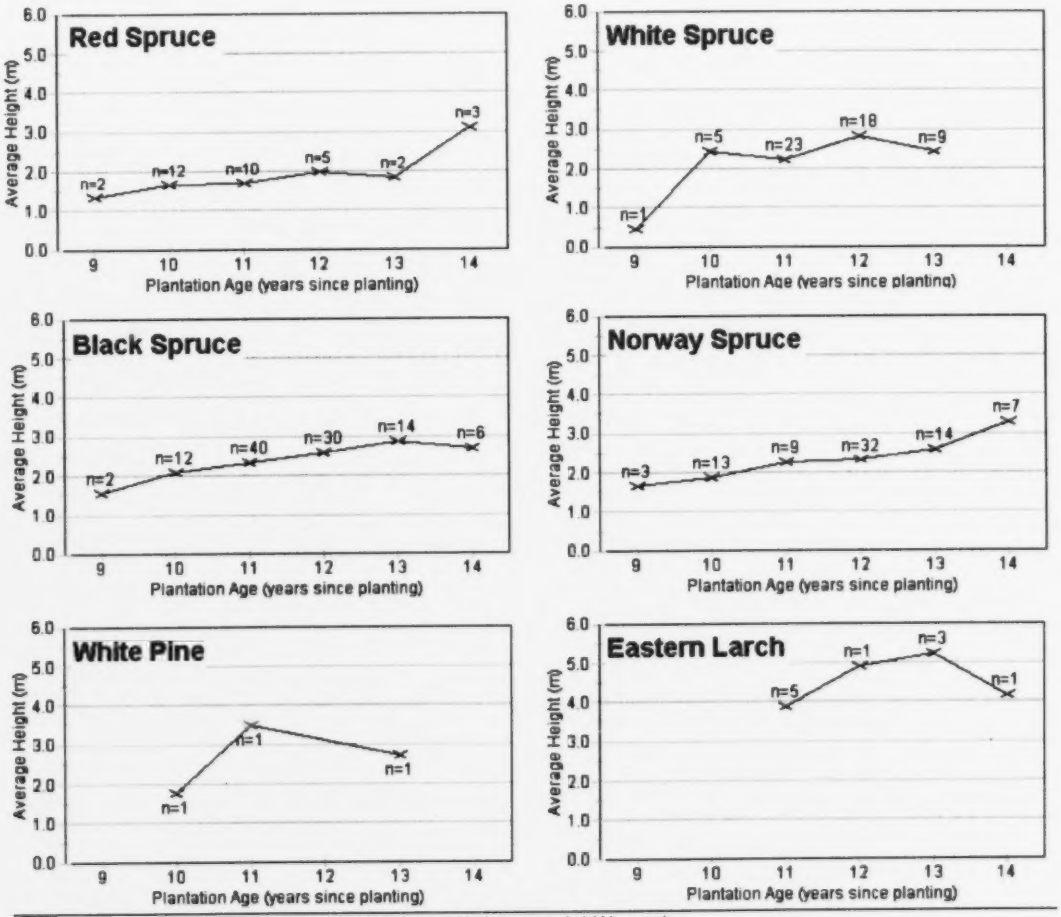


'n' refers to the number of plantations used to calculate the area weighted average leader growth by species

Figure 9. Area-weighted average leader growth by species for the for the 1993 and 2002 surveys.

Area weighted average height of plantations was plotted by species and age (Figure 10). Eastern larch was the tallest on average while white pine did not have adequate sample to make any conclusions. Of the spruces the Norway showed the best height growth eventually surpassing all spruces in average height by age 14. It was difficult to draw any conclusions for white spruce due to limited sampling in several age classes. Black spruce showed a steady accumulation in

height that exceeded Norway average heights up to age 13. The red spruce showed less height accumulation as compared with the other spruces (Figure 10), yet there is indication that height accumulation will catch up to other spruces in the years to follow. The initially slower height growth of red spruce is consistent with previous comparative work on red and black spruce (NSDLF, 1989).



'n' refers to the number of plantations used to calculate the area weighted average height by species

Figure 10. Area weighted average height by species and age.

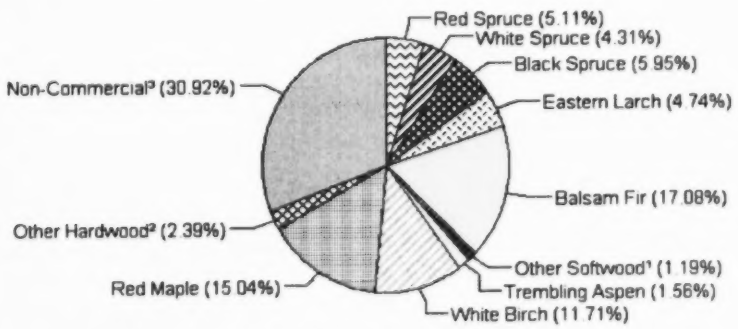
Density

Density of excess stems averaged 5,518 stems/ha and ranged from 27,428 to 129 stems/ha. Just over 65% of the surveyed area had greater than 3,000 stems/ha (Table 3). The excess stems referred to in this survey includes only stems that were at least half the height of the planted stock.

Table 3. Area distribution of excess stems/ha by density class.

Density Class	Number of Plantations	Plantation Area (ha)	Percentage of Total Area (%)	Cumulative % of Total Area
0-500	16	90.8	5.7	5.7
501-1000	13	54.0	3.4	9.1
1,001-2,000	35	184.2	11.6	20.7
2,001-3,000	29	213.6	13.4	34.1
3,001-5,000	66	405.3	25.5	59.6
5,000-10,000	75	418.8	26.4	86.0
10,000-20,000	44	200.0	12.6	98.6
20,000 +	7	22.5	1.4	100.0
Total	**285**	**1589.2**	**100.0**	**n/a**

Excess commercial softwood density averaged 2,118 stems/ha (38% of total excess stems) and ranged from 12,487 to 0 stems/ha. Balsam fir was the most abundant commercial softwood species representing 45% of the excess softwood stems followed by black spruce, red spruce, eastern larch then white spruce (Figure 11).



1: Other softwood included; White Pine, Jack Pine, Red Pine & Eastern Hemlock.
2: Other hardwood included; Largetooth Aspen, Red Oak, Beech, Yellow Birch, Sugar Maple & White Ash.
3: Non-commercial included; Grey Birch, Mountain Maple, Striped maple, Alder, Choke Cherry, Pin Cherry, Willow, Service Berry & Mountain Ash

Figure 11. Distribution of total excess stems/ha by species.

Non-commercial species and commercial hardwood each represented 31% of the excess stems. Red maple and white birch were found most frequently, making up greater than 85% of all excess commercial hardwood stems (Figure 11). The distribution of natural regeneration density by species was similar to a 1994-95 Nova Scotia clearcut regeneration survey (NSDNR, 2000). Most notable were the similarities in relative abundance of balsam fir, spruce, red maple and white birch.

Figure 12 presents a summary of average plantation ingrowth by species planted, tenure and region. It is important to note the extent of plantation maintenance (weeding, spraying, etc...) is unknown yet has a strong influence on density. Despite this, general comparisons were made across the broad stratification classes.

Regional differences in area weighted average density (Figure 12) showed the western, valley south shore and south central subdivisions to have a higher occurrence of excess stems. The other regions showed a decreasing trend moving from north central to eastern to Cape Breton. Excess commercial softwood stems showed little variation by subdivision with the exception of the south central subdivision where excess softwood stems were double the occurrence observed in other subdivisions.

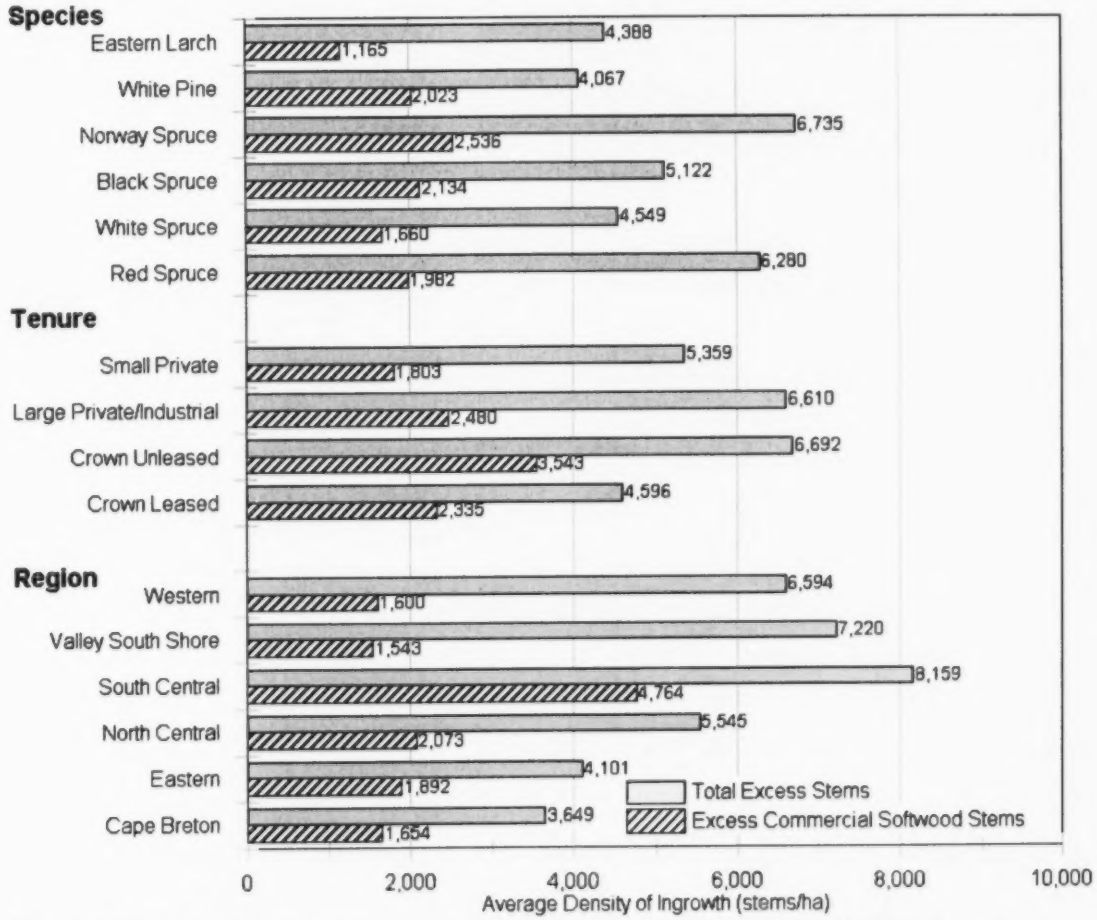


Figure 12. Area weighted average excess stems/ha by region, tenure and species.

Average excess stems did not seem to be strongly influenced by either land tenure or species planted (Figure 12). Low densities for the crown leased tenure are likely associated with underlying regional variation since this tenure is located mostly in the eastern region where excess stems were generally lower. Additionally, the higher levels of ingrowth associated with Norway and red spruce may be related to the species being relatively slow starters and having lower survival percentages as discussed previously.

The impact of excess density on the performance of plantations in terms of stocking and growth was explored. Commercial softwood stocking showed a strong correlation to the excess density of commercial softwoods (Figure 13). As the density of natural softwood increased so did the commercial stocking. Natural replacements are the primary reason for the increase. The excess density shows no apparent ill effects to stocking of planted species. The presence of softwood ingrowth appears to enhance overall stocking. This trend becomes more evident once excess softwood density reaches 3,000 stems/ha after which natural replacements increase overall commercial softwood stocking by 14% to 16%.

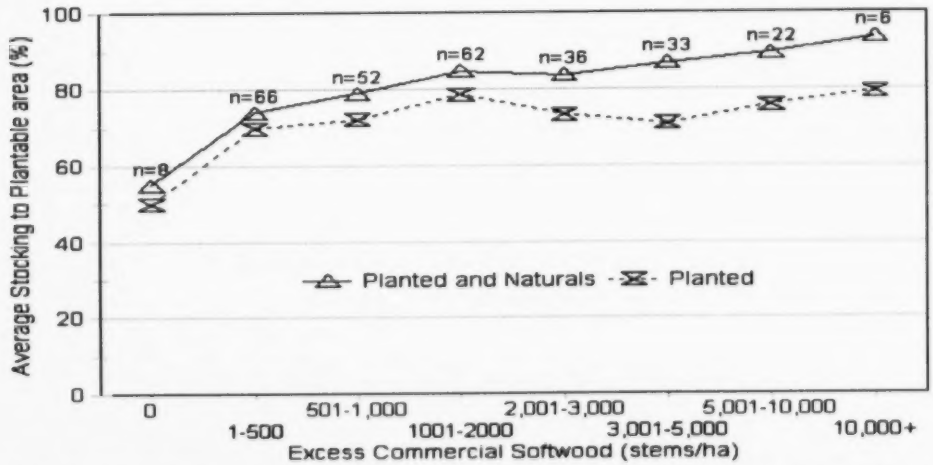
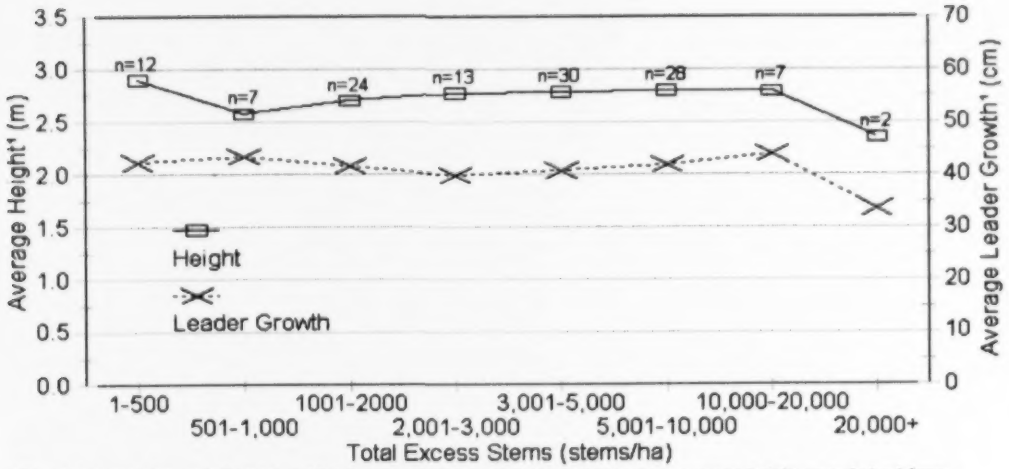


Figure 13. Average stocking to plantable area by excess commercial softwood density class.

Because of the high variability in early stand development, it is difficult to infer whether excess density is affecting plantation height and leader growth. Results of this survey suggest that average height and leader growth is not adversely affected by the density of plantation ingrowth (Figure 14).



¹ To minimize variance in height and leader growth not associated with density, average height was derived from plantations where average height of planted was less than or equal to the average height of excess stems.

Figure 14. Average height and leader growth by density class (total excess stems).

Competition

The survey assessed site competition based on a plantation wide estimate of species present along with the associated percent cover and average height. Hardwood and non-commercial vegetation averaged 29% coverage at an average height of 2.5m across the plantation area surveyed. The species, percent cover and height information was used to derive a competition index for each plantation using the following formula:

$$\frac{\sum_{i=1}^{n} (\%Cov_i \times Ht_i)}{PHt}$$

Where:

$\sum$ = Sum of all Competition Species
n = Number of Competition Species
$\%Cov_i$ = Percent Cover of Species i (%)
Ht_i = Mean Height of Species i (m)
Pht = Mean Height of Planted Species (m)

Competing vegetation included both hardwood and non-commercial species. Excess commercial softwoods were not considered in the competition index calculation. The survey showed an average competition index of 42.6 that ranged from 0 to 385. The area distribution (Figure 15) indicated that 12% of the area is experiencing severe competition with indices of greater than 100.

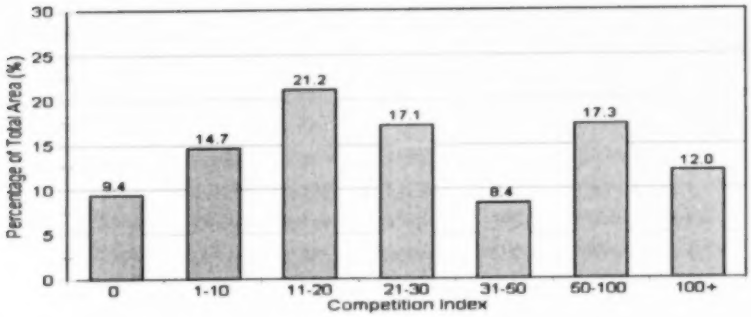


Figure 15. Competition index area distribution.

The assessment identified red maple, white birch and grey birch as the most commonly occurring competition (Table 4) that were present on 56%, 45% and 40% of all plantations surveyed respectively. Red maple was the most frequently occurring species that covered on average 10% of the plantation area it occurred on, with an average height of 2.9m. Grey birch occurred less frequently yet covered 18% of the plantation area it occurred on with an average height of 3.7m. On average, competition (2.50m) was taller than the planted trees (2.36m) yet the percent ground cover of the competition was relatively low keeping competition indices from reaching severe levels (100+ range).

Table 4. Distribution and height of major competition.

Species	Occurrence		Amount of Ground Cover[1]		Avg. Height
	Number	Percent	Hectares	Percent	(m)
Red Maple	160	56.1	100.0	9.8	2.9
White Birch	127	44.6	86.4	11.5	3.2
Grey Birch	113	39.6	113.6	18.3	3.7
Alder	55	19.3	49.6	17.5	2.3
Pin Cherry	46	16.1	28.2	9.7	3.1
Trembling Aspen	41	14.4	13.6	6.1	3.6
Willow	26	9.1	7.8	5.6	2.5
Yellow Birch	18	6.3	9.9	5.1	2.5
Sugar Maple	14	4.9	13.8	10.3	2.8
Choke Cherry	13	4.6	3.5	7.1	1.8
Largetooth Aspen	9	3.2	1.1	4.2	4.1

[1]Plantations where species did not occur were not used to derive average percent groung cover.

Occurrence of major vegetation species found in both the 2002 and 1993 plantation surveys are compared in Table 5. In 1993 the major competition was mainly grasses and small shrubs yet 10 years later the vegetation has shifted towards tree species that were present only in a minor sense in the 1993 survey. The hardwood competition identified in the 1993 survey has become established and is now the major competition in the plantations.

Table 5. Major competition species found in survey versus the 1993 survey.

2002 Survey		1993 Survey	
Species	**% Occurrence**	**Species**	**% Occurrence**
Red Maple	56	Grass spp	51
White Birch	45	Rubus spp	45
Grey Birch	40	Herbaceous spp	31
Alder	19	Alder	17
Pin Cherry	16	Red Maple	15
Trembling Aspen	14	Ericaceous spp	11
Willow	9	Pin Cherry	8
Yellow Birch	6	White Birch	7
Sugar Maple	5	Willows	4
Choke Cherry	5	Aspen	3

Figure 16 summarizes competition indices by region, tenure and planted species. Caution must be used in interrupting these trends because of the subjective nature of the vegetation assessment and incomplete knowledge of plantation treatment history. The results should only be used to suggest areas where trends may exist.

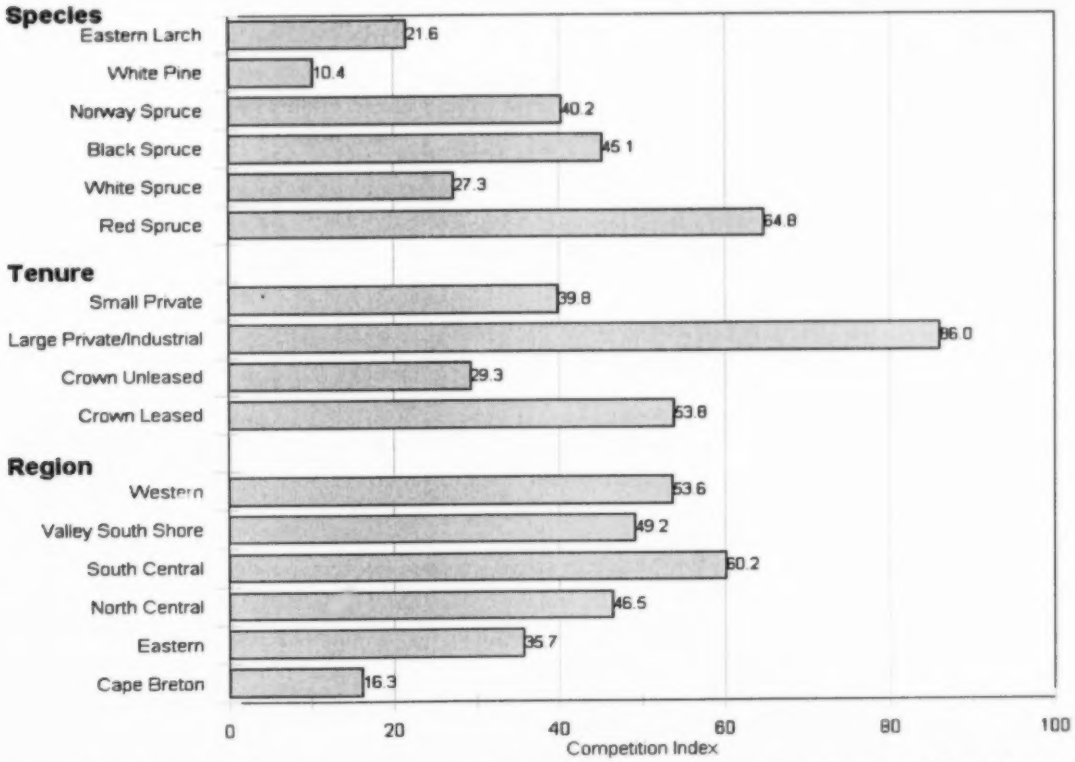


Figure 16. Area weighted average competition index values by region, tenure and species.

Competition indices increased geographically from east to west across the province (Figure 16). This was similar to the excess density trend presented earlier, indicating that competition assessments were consistent with measured densities of excess stems. The average competition indices by tenure showed the small private and crown as having relatively low competition levels versus the other tenures. Competition index values by species seemed to be controlled more by the height of planted species suggesting that competition is more of a problem for the slower growing species like red spruce. Competition on white spruce plantations was relatively low compared to other spruces.

Competition index level classes were plotted with average stocking (Figure 17). At low competition levels the average commercial softwood and planted stocking tended to be lower. The low competition level could be an indication of poor site conditions that deterred both the establishment of competition and survival of planted seedlings. Once competition indices were greater than 100, average stocking tended to drop off again. This suggests the survival of planted stock decreases once competition reaches severe levels (indices greater than 100). Results showed average stocking is relatively insensitive to competition until indices exceeded 100.

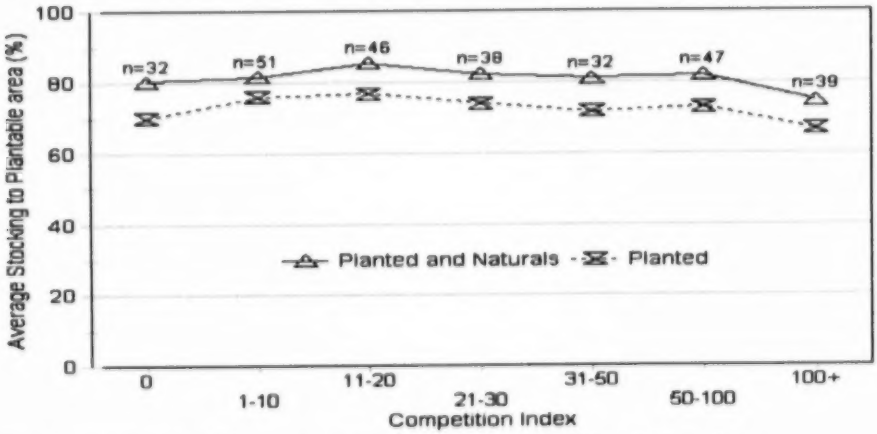


Figure 17. Area weighted average stocking by competition index class.

Analysis of height and leader growth in relation to competition indices showed that both tended to decrease with increasing competition indices (Figure 18). Average height decreased from 2.7m to 1.7m across the competition classes while average leader growth decreased from 40cm to 25cm across the same classes. Height and leader growth was affected by light to moderate competition levels unlike stocking that did not seem to be affected until severe competition levels (greater than 100) were reached.

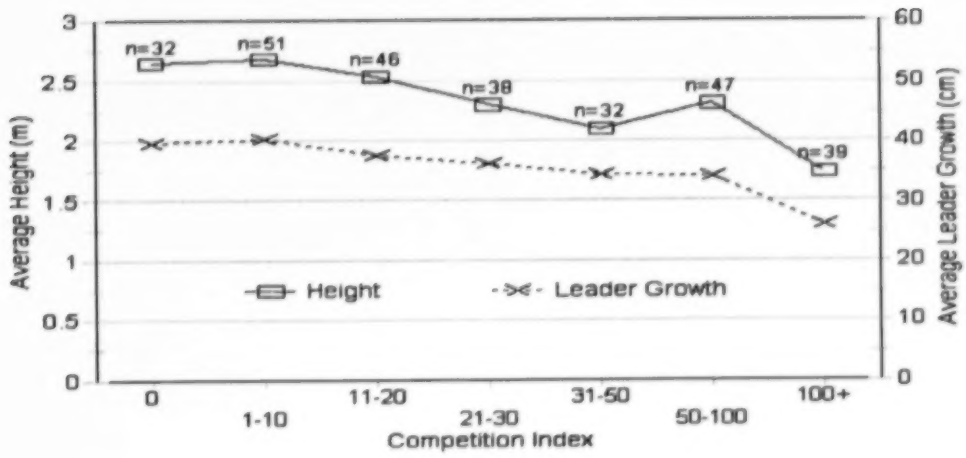
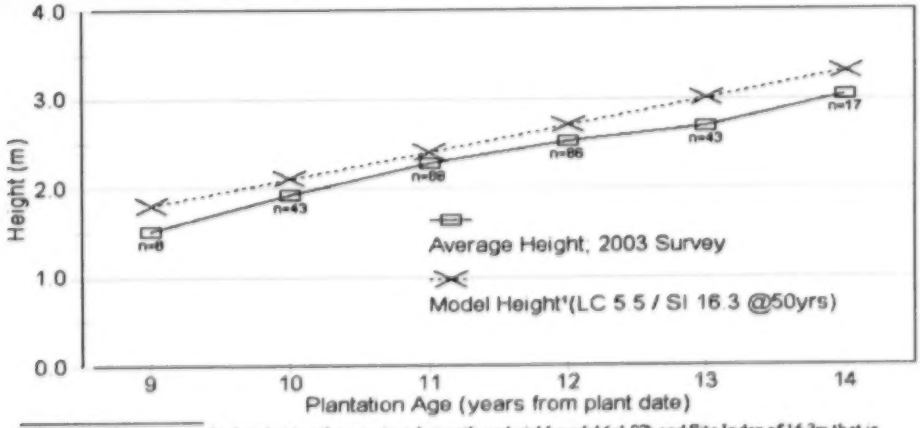


Figure 18. Area weighted average height and leader growth by competition index class.

Height and age data collected was compared to the provincial growth and yield model (NSDNR, 1993) for an indication of how competition may be affecting plantation performance in regards to height. The growth and yield model (NSDNR, 1993) was run using a land capability (LC) of 5.5m³/ha/yr (equivalent site index of 16.3m @ 50yrs) which is considered to be an average site for the province. Predicted heights for ages 9 to 14 years were compared to average heights from the survey (Figure 19). The comparison showed heights to be slightly less than what would be expected for an average site. Predicted values ranged from 1.8m to 3.3m while survey averages ranged from 1.5m to 3.0m. The decrease in heights suggest that competition is adversely affecting development of plantations in regards to height.



¹ Predicted Height was calculated using the provincial growth and yield model (v1.02) and Site Index of 16.3m that is equivilant to a land capibility of 5.5m³/ha/yr.

Figure 19. Height comparison to provincial growth and yield model (v1.02).

Free To Grow and Treatment Recommendations

The free to grow (FTG) status was calculated as the percentage of plots assessed as free to grow versus the total number of plots associated within any one plantation. The results showed that 41% of the seedlings were free to grow. Plantations that were 100% FTG represented only 18% of the plantation area surveyed while plantations that were less than 40% FTG represented approximately 56% of the area (Figure 20).

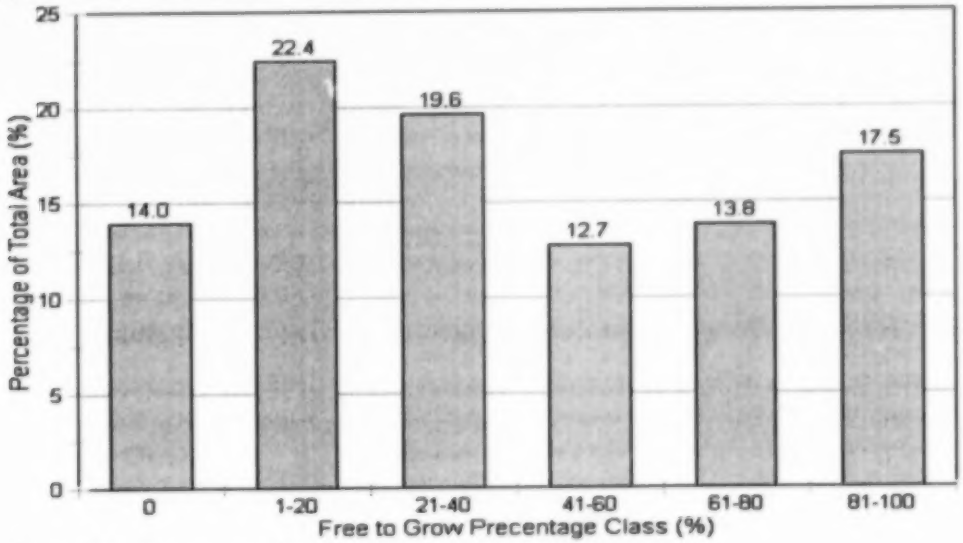


Figure 20. Percentage free to grow area distribution.

The plantation level FTG information along with the competition data collected influenced the prescriptions made at the time of assessment. Treatment recommendations were subjective yet showed consistency to both FTG and competition data collected. Table 6 summarizes the FTG, average competition height, planted stocking and competition indices associated with the treatment recommendations.

Table 6. Treatment prescription with associated free to grow and competition values.

Recommended Treatment	Number of Plantations	Plantation Area (ha)	Free to Grow (%)	Competition Height (m)	Planted Stocking (%)	Competition Index
None	119	708.8	62.6	2.1	74.2	21.2
Weeding	150	784.5	23.8	2.8	74.2	55.3
Planting	8	44.8	47.1	2.1	47.3	97.5
Spraying	8	51.1	15.6	2.2	67.5	96.2
Total	**285**	**1589.2**	**41.5**	**2.5**	**73.2**	**42.5**

For plantations where treatments were recommended the average FTG percentage was lower and competition indices higher. The results showed that 45% of the area assessed did not require any treatment (Figure 21). Of the 55% of the plantation area that required treatment 49% needed weeding, 3% needed spraying and 3% required planting. Where planting was recommended the

stocking of planted trees was considerably lower on average (Table 6). The main difference between the spraying and weeding treatment is that spraying was recommended on the assumption it would be more effective on competition less than 2m in height. The average height of competition for plantations where weeding was recommended was 2.8m compared to 2.2m for plantations where spraying was recommended.

The 55% of the area that required treatment is up from a 1985 Nova Scotia plantation survey (NSDLF, 1988) that reported 45% of plantations required treatment. The lower level of treatment required may be due to differences in site disturbance history of the 1985 assessment which included a higher percentage of old fields that tend to have less naturally regenerating competition.

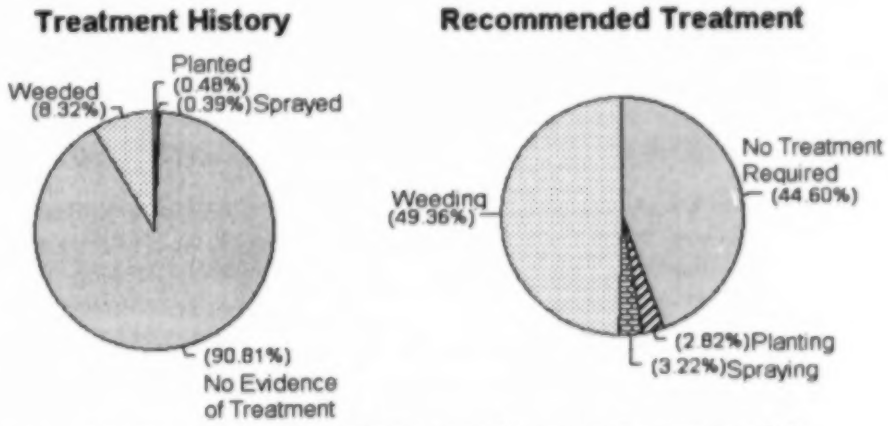


Figure 21. Area distribution of treatment history and recommended treatments across all plantations assessed.

Past plantation treatments were also noted where evidence existed. This data is obviously incomplete yet was summarized to present a general picture. Of the area assessed 91% showed no evidence of recent treatment (Figure 21). Of the 9.2% where treatment was evident 8.3% was weeded, 0.5% was planted and 0.4% was sprayed. For plantations that showed signs of past treatment, additional treatment may have been recommended depending on the condition of the plantation at the time of assessment.

Summary

A summary of the results from the 2002 plantation survey are as follows:

- Stocking of commercial softwoods (planted + natural) to plantable sites averaged 81.6% (ranging from 15% to 100%) down from the 84.9% determined in the 1993 survey.
- Stocking of planted trees to plantable sites averaged 73.2% (ranging from 8% to 98%) down from the 84.1% determined in the 1993 survey.
- Overall, 94% of the area surveyed was greater than 60% stocked to commercial softwoods, down from the 96% determined in the 1993 survey.
- Over the range of ages sampled (9 to 14 years) average commercial softwood stocking declined from 85.5% to 79.4% as plantation age increased.
- The central region showed the highest stocking levels (84.6% commercial softwood stocking) followed by eastern (81.5%) then western (77.0%). The 1993 survey showed the western region had highest stocking levels.
- Area weight average height of plantations assessed was 2.36m with average leader growth of 36cm for plantations that averaged 11.5 years of age.
- Of the spruces, Norway height and leader growth exceeded all other spruces by age 14. The white and black spruce height and leader growth was higher than Norway between ages 9-12 The slower growing red spruce showed increased growth rates in older plantations suggesting it will eventually catch up to the other spruces.
- Density of total excess stems averaged 5,518 stems/ha and ranged from 27,428 to 129 stems/ha.
- Density of excess commercial softwood stems averaged 2,118 stems/ha and ranged from 12,487 to 0 stems/ha. The most frequently occurring softwoods were balsam fir (45%) and spruce (40%).

- Regional differences indicated the western, valley-south shore and north central subdivisions to have a higher occurrence of ingrowth. The south central region showed softwood ingrowth that doubled most other subdivisions.

- Commercial softwood ingrowth enhanced stocking. This enhancement was strongest when excess softwood exceeded 3,000 stems/ha.

- Hardwood and non-commercial competing vegetation average 29% ground coverage at an average height of 2.5m across the plantation area surveyed.

- Area weighted competition index was 42.6 and ranged from 0 to 385 with approximately 12% of the area experiencing severe competition (indices greater than 100).

- Red maple, white birch and grey birch were the most commonly occurring competition and were present on nearly 50% of all plantations assessed.

- Competition showed no detrimental effect on stocking until indices exceeded 100.

- Height and leader growth was affected by light to moderate competition levels.

- Of the plantation area surveyed 41% of seedlings were free to grow. FTG status of plantations ranged from 0% to 100% and plantations that were 100% free to grow represented only 18% of the area surveyed.

- Plantation level treatment prescriptions showed that 45% of the area surveyed did not require treatment at the time of assessment. Of the 55% that required treatment 49% needed weeding, 3% needed spraying and 3% needed planting.

Discussion

All forest management is based on the principle that management activities (harvesting, reforestation, vegetation control) create a forest condition that provides the desired values in the desired amounts over time. These activities are arguably the most important component of forest management as they are the mechanism by which managers can influence the forest composition, structure and pattern. Plantation silviculture is one such reforestation activity that is widely used in Nova Scotia.

Plantations can be a powerful means of influencing the forest condition. Smith (1986) states that re-establishing a new forest by way of planting is one of the most costly reforestation tactics. However, the benefits can be very high and in many cases the cost benefit ratio of planting is higher than any other tactic. Yet there are many circumstances, like aggressive competition, that can lead to costly failure.

Competition can suppress the planted stock causing growth delays or where competition is severe individual trees may be lost which will reduce yield at rotation. For example, if the forecasted yield of a plantation is 270 m^3ha^{-1} at age 60 years the mean annual increment (MAI) at rotation would be 4.5 $m^3ha^{-1}yr^{-1}$. If competition caused a 5 year delay in the accumulation of the stand volume the MAI is reduced to 4.2 $m^3ha^{-1}yr^{-1}$. If competition caused a reduction in stems and only 250 m^3ha^{-1} a was achieved at rotation, the MAI is further reduced to 3.8 $m^3ha^{-1}yr^{-1}$. Under this scenario there is a 0.7 $m^3ha^{-1}yr^{-1}$ or 16% reduction in MAI at rotation. At the forest level the costs can be far greater where plantations have facilitated an allowable cut effect based on control of competition yet there is failure to exercise that control operationally (Baskerville, 1984). The results of this survey showed that on average 59% of seedlings were not free to grow and plantations were 81.6% percent stocked indicating that growth delays and reductions in yield have already occurred.

In the management process there has to be a decision at the site level of whether to use planting as the reforestation method. There can be many factors that influence whether a site should be planted such as the natural regeneration potential of a site. The results of this survey suggest there were many sites planted that had sufficient natural regeneration to re-establish softwood stands. This was consistent with a 1995 clearcut regeneration survey (NSDNR, 2000) that reported natural softwood stocking averaged 72% on softwood clearcuts. Depending on management objectives, the benefits of planting are generally higher where a naturally regenerating softwood stand is not likely to occur. Where timber is the primary goal of management, planting should be given priority to those areas where planting is most rewarding (Smith, 1986).

Once a decision has been made to use planting, an associated maintenance schedule must be designed and followed to ensure the plantation is established and remains free to grow on the site. This survey showed plantations that were 100% free to grow represented only 18% of the area surveyed. The level of planning and plantation maintenance necessary depends on the situation. Some may require no maintenance while others require much effort to deal with issues like competition. This survey showed a wide range of competition levels across the plantations surveyed. Free to grow status of plantations ranged from 0% to 100% with only 41% of seedlings free to grow suggesting there is opportunity to minimize delays and reductions to future yields.

Management Recommendations

Monitoring plays a key role in ensuring that plantations are achieving intended results. Further, where evidence exists that competition is suppressing plantation growth and development, tending operations should be implemented. According to this survey, moderate-heavy competition (indices greater than 30) exists on approximately 55% of the area surveyed, suggesting many plantations are not getting the required maintenance. In addition, many of the sites surveyed appeared to have been sufficiently stocked with naturals, making planting extraneous. More thorough surveys before planting may prevent incurring unnecessary planting costs.

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Appendix I. Plantation Stocking Survey Summary Data

Summary Category	Plantations Sampled		Plot	Stocking		Growth(cm)		Ingrowth (stems/ha)				Hardwood/Non-Commercial Competition			Free to Grow %	Plantation Age(years)
	Count	ha	Count	PSP[1]	PSPN[2]	Height	Leader	Softwood	Hardwood	Non-Com.	Total	% Cover	Height(m)	Index		
Overall	**205**	**1589.20**	**5564**	**73.23**	**81.59**	**2.36**	**0.36**	**2118**	**1694**	**1706**	**5518**	**29**	**2.5**	**42.59**	**41.48**	**11.5**
Region																
Eastern	105	614.60	2019	73.52	81.54	2.58	0.40	1821	1495	660	3967	24	2.1	29.95	48.88	11.6
Central	106	594.10	2136	77.18	84.55	2.21	0.33	2776	1501	1951	6228	31	2.9	50.05	39.32	10.8
Western	74	380.50	1409	66.62	77.03	2.22	0.32	1571	2315	3028	6914	33	2.4	51.36	32.92	12.5
Subdivision																
Cape Breton	37	182.70	636	70.60	80.02	2.59	0.38	1654	1541	453	3649	14	1.6	16.26	45.55	11.6
Eastern	68	431.90	1383	74.76	82.18	2.57	0.41	1892	1476	733	4101	28	2.4	36.74	50.29	11.5
North Central	81	438.90	1608	76.87	83.03	2.26	0.34	2073	1408	2064	5545	30	2.8	46.46	39.84	10.9
South Central	25	155.20	528	78.04	88.86	2.07	0.29	4764	1764	1631	8159	34	3.2	60.18	37.83	10.5
Valley South Shore	37	194.40	731	62.84	75.18	2.04	0.29	1543	1978	3698	7220	32	2.3	49.17	24.41	12.1
Western	37	186.10	678	70.56	78.96	2.41	0.36	1600	2666	2329	6594	34	2.4	53.64	41.81	12.9
Land Tenure																
Crown Leased	12	168.90	430	75.70	84.46	2.49	0.39	2335	1599	663	4596	38	2.9	53.80	44.10	11.6
Crown Unleased	22	201.00	604	73.48	82.82	2.17	0.31	3543	2132	1017	6692	21	2.3	29.28	38.60	11.1
Industrial	3	11.80	42	63.34	84.66	2.05	0.28	6798	1722	3630	12150	31	2.3	57.20	0.00	10.7
Large Private	10	78.90	244	77.01	81.39	2.17	0.37	1835	2701	1245	5781	44	3.1	90.34	41.56	10.4
Small Private	238	1128.60	4244	72.66	80.92	2.38	0.36	1803	1559	1997	5359	28	2.4	39.79	42.03	11.6
Dominant Species																
Red Spruce	34	169.80	619	67.66	78.73	1.82	0.28	1982	1979	2319	6280	29	2.6	64.83	39.05	11.0
White Spruce	56	270.80	967	74.36	80.50	2.45	0.37	1660	1385	1504	4549	22	2.2	27.34	48.39	11.6
Black Spruce	104	743.20	2440	77.20	84.40	2.43	0.36	2134	1514	1473	5122	31	2.6	45.15	42.69	11.5
Norway Spruce	78	377.90	1373	67.89	78.49	2.28	0.36	2536	2194	2005	6735	29	2.4	40.16	34.68	11.5
White Pine	3	4.40	30	66.14	84.63	2.21	0.39	2023	966	1078	4067	11	1.1	10.38	18.64	10.8
Eastern Larch	10	23.10	135	62.34	75.00	4.12	0.53	1165	947	2276	4388	23	2.5	21.60	48.81	11.8
Plantation Size Class (ha)																
00.0-02.0	57	73.10	583	69.08	79.31	2.51	0.37	2482	2501	2789	7771	29	2.6	51.15	28.97	11.7
02.1-04.0	60	234.00	914	70.07	80.12	2.36	0.36	2082	2108	2009	6199	28	2.3	41.94	36.83	11.6
04.1-06.0	61	304.20	1106	72.44	81.16	2.36	0.36	1799	1462	1572	4833	25	2.5	40.92	47.64	11.7
06.1-08.0	39	270.10	986	72.80	81.30	2.19	0.32	1992	1395	2400	5787	30	2.8	46.44	34.50	11.5
08.1-10.0	14	125.10	440	67.91	79.51	2.33	0.34	1941	2863	2534	7337	31	2.5	51.03	36.15	11.4
10.1-12.0	12	136.40	466	75.99	79.74	2.29	0.37	1058	1089	2410	4558	43	2.6	63.43	43.26	11.4
12.1+	22	446.30	1070	77.03	84.35	2.46	0.38	2746	1540	593	4879	26	2.3	31.60	46.95	11.3
Plantation Plant Year																
1989	86	507.40	1741	75.79	83.95	2.55	0.38	1841	1796	1621	5258	33	2.6	45.02	47.88	12.2
1990	118	618.20	2173	71.06	80.40	2.41	0.36	2143	1579	1523	5244	24	2.4	36.56	38.72	11.6
1991	81	463.60	1650	73.34	80.58	2.07	0.33	2389	1734	2043	6166	30	2.5	47.97	38.16	10.6
Plantation Plant Month																
April	10	60.30	232	75.35	85.39	2.10	0.27	2795	1486	753	5034	25	1.8	23.26	39.99	11.2
May	148	825.60	2896	74.65	82.03	2.41	0.37	1680	1613	1734	5026	30	2.4	45.17	45.94	11.5
June	68	369.60	1269	72.30	80.65	2.59	0.39	1972	1979	1812	5764	27	2.6	35.01	36.86	12.2
July	13	65.90	234	67.94	78.52	2.19	0.31	2518	1767	1967	6251	31	2.9	43.18	34.89	11.2
August	23	117.40	418	73.51	81.26	2.07	0.32	2182	1564	1435	5181	31	3.0	70.35	36.19	10.9
September	23	150.20	515	69.04	81.54	1.86	0.30	4391	1589	1768	7749	21	2.1	32.84	36.0	10.2

Appendix I. Plantation Stocking Survey Summary Data (con't)

Summary Category	Plantations Sampled Count	Plantations Sampled ha	Plot Count	Stocking PSP[1]	Stocking PSPH[2]	Growth(m) Height	Growth(m) Leader	Ingrowth (stems/ha) Softwood	Ingrowth (stems/ha) Hardwood	Ingrowth (stems/ha) Non-Com.	Ingrowth (stems/ha) Total	Hardwood/Non-Commercial Competition % Cover	Hardwood/Non-Commercial Competition Height(m)	Competition Index	Free to Grow %	Plantation Age(years)
Plantation Age at Remeasurement																
9	8	55.70	162	74.78	85.52	1.51	0.26	8152	1907	318	10378	14	2.1	23.89	25.45	9.0
10	43	277.80	937	73.66	81.69	1.92	0.30	2003	1579	1533	5115	29	2.6	52.83	45.07	10.0
11	88	495.40	1782	74.48	82.34	2.27	0.36	2253	1213	1549	5015	31	2.5	46.66	50.34	11.0
12	86	459.10	1597	72.25	80.65	2.52	0.37	1762	1962	2059	5783	28	2.4	39.07	36.93	12.0
13	43	194.40	725	73.48	81.84	2.68	0.38	1481	1913	1363	4757	23	2.2	28.92	39.86	13.0
14	17	106.60	361	69.34	79.38	3.04	0.43	1337	2557	2711	6604	40	3.0	46.80	21.94	14.0
Plantation Stocking Class[3] (planted and natural)																
000-020	1	2.60	10	7.50	15.00	0.34	0.07	361	0	1227	1588	65	0.9	169.12	40.00	10.0
021-040	4	15.30	71	31.76	36.43	0.89	0.13	137	1374	4393	5904	42	2.7	134.00	25.88	11.4
041-060	22	82.00	318	48.27	54.51	1.71	0.26	805	1551	4110	6466	44	2.5	85.41	33.13	11.2
061-080	69	503.30	1753	64.46	73.76	2.38	0.37	1241	1857	1938	5035	28	2.3	38.74	40.89	11.7
081-100	169	986.00	3412	80.61	88.71	2.43	0.36	2711	1632	1347	5689	26	2.6	39.24	42.73	11.4
Excess Commercial Softwood Density Class (stems/ha)																
00000-00000	8	17.50	91	49.79	54.83	2.00	0.27	0	2547	4567	7114	52	2.9	64.27	45.18	11.7
00001-00500	66	343.20	1255	69.68	73.97	2.30	0.36	252	1526	2132	3911	28	1.9	47.70	60.87	11.6
00501-01000	52	322.70	1133	71.99	79.00	2.57	0.39	736	2118	2368	5222	37	2.6	49.44	42.91	11.9
01001-02000	62	362.70	1255	78.54	84.68	2.42	0.36	1431	1505	1287	4224	26	2.6	32.53	40.55	11.5
02001-03000	36	200.30	670	73.31	83.65	2.37	0.35	2548	1992	1682	6221	32	2.7	47.14	25.89	11.3
03001-05000	33	199.00	669	70.96	86.78	2.18	0.34	4113	1152	552	5817	21	2.7	33.08	40.08	11.2
05001-10000	22	91.90	375	75.73	89.48	2.23	0.32	6426	1404	1901	9731	27	2.5	49.06	25.56	11.3
10001-20000	6	51.90	126	79.28	93.60	1.85	0.28	11632	2633	894	15159	21	2.9	36.58	3.47	10.0
Total Excess Stems (Softwood, Hardwood & Non-Commercial) Density Class (stems/ha)																
00001-00500	16	90.80	303	72.90	77.36	2.64	0.39	146	113	23	282	4	0.5	4.98	94.06	11.8
00501-01000	13	54.00	204	70.45	74.19	2.06	0.35	347	251	142	739	4	2.0	7.34	82.99	10.9
01001-02000	35	184.20	657	72.25	79.33	2.43	0.39	749	591	224	1564	22	1.9	26.02	67.14	11.4
02001-03000	29	213.60	662	79.10	82.94	2.34	0.35	1108	643	624	2375	15	2.7	22.80	60.12	11.3
03001-05000	66	405.30	1440	73.41	82.46	2.48	0.37	1869	1429	834	4133	28	2.6	32.80	35.33	11.7
05001-10000	75	418.80	1458	72.46	82.47	2.37	0.36	2837	2434	1777	7047	35	2.8	57.95	28.32	11.5
10001-20000	44	200.00	742	69.00	82.02	1.94	0.29	4927	3336	5487	13750	50	2.8	85.19	7.59	11.2
20001+	7	22.50	98	82.40	86.08	2.55	0.31	1269	6929	15420	23618	88	3.4	114.30	0.00	11.8
Competing Vegetation Index																
000-000	32	149.50	528	69.94	80.41	2.65	0.40	1352	163	89	1604	0	0.0	0.00	79.08	11.4
001-010	51	232.90	899	75.88	81.53	2.68	0.40	1407	998	593	2998	6	2.3	5.38	63.37	11.8
011-020	46	336.20	1042	76.77	86.37	2.54	0.38	2523	1268	827	4618	17	2.4	14.51	41.93	11.6
021-030	30	272.10	868	74.05	82.29	2.30	0.36	2913	1918	596	5427	24	2.5	24.51	41.98	11.4
031-050	32	134.10	543	71.64	81.11	2.10	0.34	2046	2720	914	5680	32	2.7	38.54	31.57	11.5
051-100	47	274.20	975	72.89	81.91	2.31	0.34	2285	2158	3419	7862	51	3.2	69.05	28.15	11.4
101+	39	190.20	709	66.80	74.77	1.74	0.26	1549	2787	5569	9905	73	3.7	161.82	9.84	11.3
Past Treatment History Class																
Planted	3	7.60	37	52.73	57.31	1.90	0.31	1229	606	79	1914	3	2.8	7.42	65.00	12.0
Sprayed	1	6.20	22	81.40	82.56	1.42	0.14	230	459	33	722	3	3.0	6.34	95.00	10.0
Untreated	255	1443.20	5008	73.87	82.00	2.37	0.36	2203	1633	1657	5492	29	2.5	43.96	41.25	11.5
Weeded	25	132.20	497	67.15	78.48	2.27	0.34	1336	2481	2414	6230	29	1.8	31.33	39.02	11.8

Appendix I. Plantation Stocking Survey Summary Data (con't)

Summary Category	Plantations Sampled		Plot	Stocking		Growth(m)		Ingrowth (stems/ha)				Hardwood/Non-Commercial Competition			Free to	Plantation
	Count	ha	Count	PSP[1]	PSP[2]	Height	Leader	Softwood	Hardwood	Non-Com.	Total	% Cover	Height(m)	Index	Grow %	Age(years)
Recommended Treatment Class																
None Required	119	708.80	2486	74.19	80.66	2.47	0.37	1137	1225	988	3349	17	2.1	21.17	62.69	11.5
Plant(Fill or Replant)	8	44.80	164	47.37	53.13	1.11	0.18	445	656	4591	5692	37	2.1	97.54	47.17	11.0
Spray	8	51.10	187	67.58	75.41	1.65	0.26	1357	2154	6532	10044	66	2.2	96.26	15.64	11.7
Weed(Full or Partial)	150	784.50	2727	74.22	84.45	2.37	0.36	3150	2147	1875	7172	36	2.8	55.31	23.77	11.5
Free to Grow (FTG) Class																
000-000	61	221.70	910	66.36	78.66	2.02	0.28	2849	3277	5456	11582	60	3.3	117.58	0.00	11.8
001-020	56	356.00	1173	75.09	84.20	2.44	0.36	3329	1943	1930	7202	32	2.7	44.26	10.76	11.5
021-040	49	312.00	1066	71.03	79.73	2.35	0.36	1700	2153	1337	5190	30	2.6	37.24	31.14	11.7
041-060	42	202.00	763	74.47	81.79	2.40	0.35	1880	1371	977	4227	23	2.6	28.60	52.96	11.5
061-080	32	219.40	693	70.73	78.69	2.38	0.40	1777	638	598	3012	19	1.9	23.86	71.23	11.2
081-100	45	278.10	960	79.88	84.79	2.47	0.37	898	664	246	1808	10	1.8	11.61	93.69	11.2
Average Height Class (cm)																
000-150	38	166.40	644	54.55	66.04	1.07	0.16	1753	1517	3039	6309	39	2.1	90.68	34.09	11.0
151-200	60	325.70	1156	73.50	83.58	1.77	0.28	3151	2025	1583	6759	31	2.7	54.42	35.56	10.8
201-250	68	454.20	1518	76.04	83.25	2.25	0.36	2245	1123	1646	5015	28	2.5	37.73	45.69	11.3
251-300	64	351.80	1309	76.62	83.82	2.73	0.40	1665	1822	2008	5495	29	2.5	34.95	46.36	11.8
300+	56	291.10	938	75.15	82.95	3.47	0.49	1521	2160	808	4489	22	2.4	18.68	39.88	12.5

Note

a All summary values reported are plantation averages weighted by area

b Competition index was calculated as [Total % Cover of Vegetation Species * Mean Height of Vegetation Species] / Mean Height of Planted Species
> where 'Vegetation Species' included all hardwood and Non-commercial Vegetation
> and 'Mean Height of Vegetated Species' was weighted by percent cover of each species

c Species associated with ingrowth categories included
> Softwood - Red Spruce, White Spruce, Black Spruce, Norway Spruce, Englemen Spruce, White Pine, Red Pine, Jack Pine, Eastern Larch, Eastern Hemlock & Balsam Fir
> Hardwood - Trembling Aspen, Largetooth Aspen, Red Oak, Beech, White Birch, Yellow Birch, Sugar Maple, Red Maple & White Ash
> Non-Commercial - Mountain Maple, Striped Maple, Alder, Choke Cherry, Pin Cherry, Willow, Service Berry, Mountain Ash & Apple

1 - Stocking of plantable area to planted trees
2 - Stocking of plantable area to planted and natural trees